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9 **FINAL SUMMARY REPORT.** 26 May 52-31 Jan 53.

6 A Method for Direct-Measurement of the Energy of Rupture of Impact Specimens.

* *

RESEARCH ON IMPACT TESTING

A950340

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PROJECT No.

CONTRACT No. 15 DA-19-020-ORD-1792

10 F.C. Hutchison

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This is a Final Summary Report of the work which has been performed under the requirements of Contract DA-19-020-ORD-1792, entitled "Research on Impact Testing".

Technical supervision of the contract was performed by the Watertown Arsenal. The contract was administered by the Boston Ordnance District.

The objective was a "theoretical study to determine the feasibility of developing, designing, and constructing apparatus for the impact testing of ferrous and non-ferrous specimens and materials under various conditions of striking velocity, including high-velocity, at room temperature and at low temperature".

Date of Contract	- 26 May 1952
Required Completion Date	- 1 March 1953
Delivery of Final Report	- 1 April 1953
Date of this Report	- 19 January 1953

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SUBMITTED BY:
HESSE-EASTERN CORP.
Cambridge 38, Mass.

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11, 12	Hesse-Eastern Corp. Cambridge, Massachusetts

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HESSE-EASTERN CORPORATION

Cambridge 38, Massachusetts

A. FOREWORD

It is believed by authorities in the field of physical testing that the dynamic characteristics of a material under impact conditions may be a function of the velocity of impact. Some experimental work has been done in this field which in general confirms this opinion. However the validity of the data is questionable because of either or both of the following factors:-

1. The particular design of the test apparatus used.
2. Mechanical or instrumental errors in the measurements of striking velocity and energy of rupture.

In view of the dearth of knowledge on this subject, there exists a definite requirement for a research tool of high precision and flexibility of operation which will be capable of exploring impact phenomena. A complete evaluation of this behavior may well require further experimental data than simply the correlation of striking velocity with the total energy of rupture. Such further data may need to be concerned with one or more of the following items.

1. Geometry and elastance of the striking surface.
2. The changing nature and magnitude of the striking force.
3. The varying amounts of the energy absorbed by the test specimen as a function of the specimen displacement.
4. The nature and magnitude of the deceleration of the striking member during the rupture cycle.

There currently exists some incompatibility of observed impact values among various users of standardized impact testing apparatus. This may be due to inaccurate calibration of the apparata or careless maintainance of the equipment, or inherent lack of sufficient precision in the measurement of rupture energy.

B. OBJECTIVES OF THE CURRENT INVESTIGATION

Prior to the execution of this contract, several conferences were held with technical representatives of the Mechanical Testing Section of Watertown Arsenal to discuss the problem of designing and building a high velocity impact testing device. It was initially proposed to negotiate a contract having this objective.

Subsequent study of this problem by the engineering staff of the Hesse-Eastern Corp. disclosed certain factors which indicated the desirability of changing the objective from that originally envisioned. This was necessitated by the difficulty in arriving at a satisfactory scope of work for the contractual needs, together with the extreme difficulty of estimating at all realistically the costs of a program in which it was apparent that a considerable number of intangible factors were involved and where their relative magnitude could not be estimated short of actually performing the required research upon them. There was, furthermore, no clear-cut indication that the final objective of a prototype operating model could be achieved. Following a discussion of this situation, an alternate scope was prepared and was subsequently effectuated as Contract DA-19-020-ORD-1792 wherein the objective was an engineering feasibility study of the problem to determine the practicability of the previously cited objective. This contract was executed on 26 May 1952 and the several engineering studies outlined in the scope of the contract have progressed to the point where certain definite conclusions and recommendations can be justified.

The purpose of this report is to review the course which this investigation has followed and to summarize our technical findings.

C. BASIC ELEMENTS OF AN IMPACT TESTING SYSTEM

For the analytical purposes of this investigation, the system for impact testing was broken down into the following elements:-

1. Input energy, - the type and magnitude of the initial energy in the system at the moment of initial contact of the striker upon the test specimen.
2. The magnitude and disposition of residual system energy, - following rupture of the test specimen.
3. Specimen mounting, - relation of the specimen and its mounting fixture to the striking member.
4. Specimen positioning, - the means for moving the specimen into striking position.
5. Methods for measuring the energy of rupture.

These five elements, in conjunction with the requirements of a high striking velocity and a relatively high accuracy in the measurement of rupture energy, establish the major parameters of a complete testing mechanism. From a study of these various factors individually and in combination, specific conclusions can be reached, the effect of which is to narrow the area of potential solutions for a theoretical system. These generalised conclusions may be stated as follows:-

1. The Linear System should be discarded as impractical.
2. The Rotary System appears theoretically feasible.
3. Input energies at high striking velocities may exceed the required maximum energy of rupture by a ratio of 5,000 or more to 1.
4. An acceptable accuracy in the measurement of rupture energy can be obtained only by a direct measurement of this energy.

D. DISCUSSION

The basis for arriving at these conclusions is discussed briefly in the following paragraphs. A considerable amount of engineering time was required for this evaluation, the details of which have previously been reported. The purpose at this time is to review only those elements of primary significance.

1. Linear System:-

The essential elements of a Linear System can be considered to consist of:

a. A striking member of sufficient mass to supply the required input energy.

b. A means for guiding and accelerating this mass to the required terminal striking velocities. For example, an air gun principle.

c. A means for supporting the test specimens and for disposing of the fractured pieces.

d. A receiver mechanism for decelerating this mass following specimen rupture.

It has been determined, as a later section of this report will discuss in some detail, that the only practical means for obtaining sufficient accuracy in the energy of rupture is to measure this energy directly. This requirement imposes rather severe limitations upon the design of the air gun; to wit, the accelerated mass must be limited rigorously to translatory motion only. This means that the cross-section of the air gun must be rectangular in shape to preserve true linearity of motion. Although this is not an impossible condition, it becomes highly impractical from the standpoint of manufacture and maintainance.

The following tabulation indicates certain physical properties of a system of this kind.

TABLE I - PROPERTIES OF THE STRIKING MASS

Slug Length* in inches	Slug Weight* in lbs.	Energy in ft-lbs @ 17 fps	Energy in ft-lbs @ 500 fps
12	7.7	34.4	29,500
84	53.5	241.0	208,000

*These lengths and weights are for a uniform cross-section of 3/4" x 3" and are exclusive of the specimen striker.

It becomes apparent that a major problem, bordering upon the impractical, is involved in designing a satisfactory deceleration apparatus for absorbing the residual energy in the system after high velocity impact. It appears extremely unlikely that a satisfactory means can be devised for disposing of the fractured elements of both the Izod and Charpy specimens without creating an interference with the deceleration apparatus. Furthermore, it does not appear possible to use this kind of system for testing the impact tension specimen. It is therefore our opinion that a Linear System does not provide a satisfactory solution for the contractual requirements of this investigation.

2. Rotary System:-

The essential elements of a Rotary System consist of:

a. A rotating disc suitably mounted and journalled and having sufficient rotative velocity and inertia to satisfy the energy and striking requirements of the test specimens.

b. A holding fixture and positioning mechanism for locating the specimen in proper striking position with respect to a projecting lug attached to the disc. This lug might be a fixed, external projection or might be radially guided on ways to move beyond the periphery of the disc, into striking position.

c. A power drive and hydraulic or friction braking means.

The dimensions and properties of the rotating disc, for various assumed values, are indicated in the following tabulation.

TABLE II - PROPERTIES OF THE ROTATING DISC

Rotor Dia.* in inches	Weight in lbs	Speed in rpm		Energy in ft-lbs	
		@ 17 fps	@ 500 fps	@ 17 fps	@ 500 fps
12	24	325	9550	54	46,700
32	171	122	3580	380	330,000
60	600	65	1910	1350	1,170,000

*Assuming a constant thickness of 3/4"

In this system as with the Linear System it is to be noted that the initial energy very greatly exceeds the rupture energy for maximum striking velocities. But for the Rotary System, the dissipation of the residual energy is easily accomplished by one of several braking means which can be applied to the disc following specimen rupture.

A Rotary System appears capable of being adapted to impact testing of the tension specimen as well as the Izod and Charpy specimens. There is, however, a difficult design problem inherent in this system. This relates to the apparatus for positioning the specimen within the periphery of the striker in the relatively short time interval available for the purpose. Design layouts have been studied of several schematic arrangements of a suitable mechanism. Approximate analyses have been made of spring-mass analogs which indicate that a specimen movement of approximately 3/4" can be accomplished in 12 milliseconds. This time provides a slight safety margin for the preferred striking circle diameter of approximately 32 inches. It may, however, be necessary to increase this diameter somewhat. The following tabulation indicates the relation of available time to rotor diameter.

TABLE III - AVAILABLE SPECIMEN POSITIONING TIME

Rotor Dia. in ins.	Time, in Milliseconds, for 330° of rotation	
	@ 17 fps	@ 500 fps
12	170	5.7
32	453	15.4
60	884	28.8

More extensive analysis and experimental confirmation of performance characteristics will need to be performed on one or more actual mechanisms during the development phase of this project. However, we feel that the positioning problem can be satisfactorily accomplished for all three types of test specimen.

3. Methods for Measuring the Energy of Rupture:-

There are three methods by which the energy of rupture can be measured. These methods are independent of the geometry of the dynamic system for rupturing the specimen. However, the following comments are considered to apply specifically to the Rotary System. These three methods are:

1. Measurement of the energy in the dynamic system both before and after rupturing the specimen, whereby the difference between the two measurements becomes the energy of rupture.

2. Indirect measurement of rupture energy through the absorption of this energy into a pendulum or other device which supports the specimen during rupture.

3. Direct measurement of rupture energy through the measurement and integration of the rupturing force versus its displacement.

> Note: A definition of the energy of rupture was arrived at through a joint conference between representatives of Watertown Arsenal and the Hesse-Eastern Corp. The definition agreed upon was in substance as follows: "The energy of rupture can be presumed to be the integral of the instantaneous

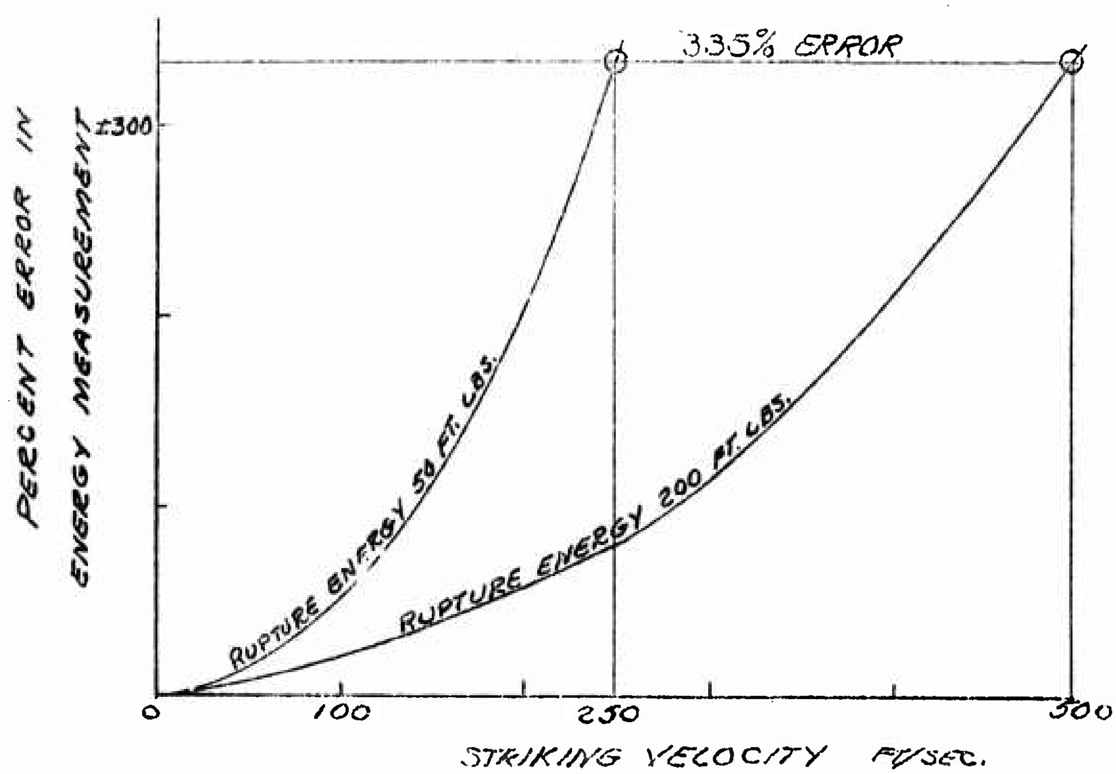
force applied to the specimen with respect to the corresponding displacement of the specimen."

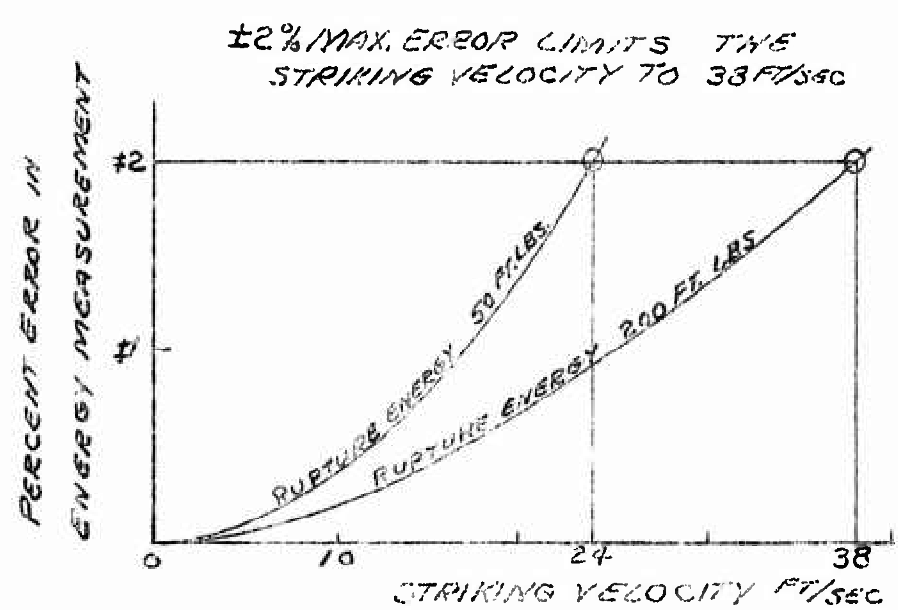
The measurement of rupture energy by the "before-and-after" method is completely impractical because of the large magnitude of energy in the system at high velocities, and the insignificant amount of this energy which is abstracted from the system during test. This energy is presumed to be measured by measuring the rotative velocity of the disc both before and after rupture of the test specimen, from which $\Delta E = \frac{1}{2} I (W_1^2 - W_2^2)$. A probable error in these velocity measurements of 1 part in 1000 is about the maximum precision which can reasonably be expected. If the resulting error in ΔE is limited to $\pm$ 2%, the striking velocity cannot exceed 40 fps at ΔE = 200 ft-lbs; or 24 fps at ΔE = 50 ft-lbs. At 500 fps, this error becomes as high as $\pm$ 335%. This situation is graphically represented in Figure 1.

The second method utilizes an indirect "measurement by energy transfer" technique. This is a method whereby the rupture energy is transferred to some supporting member free to move, such as a pendulum. Knowing the characteristics of the pendulum, its resulting motion is determined and translated into energy terms. This is the means used in the Mann machine, and a thorough analysis of it has been made in the Swann Report. The system is theoretically practical on the assumption that the pendulum and associated elements attached thereto constitute a completely rigid system, and that the "rupture time" of the specimen exceeds the time required for the shock wave (generated by the striking force) to travel to the pendulum support.

FIGURE I

MAXIMUM PROBABLE ERROR IN MEASURING RUPTURE ENERGY BY THE "BEFORE AND AFTER" METHOD





The theory breaks down in practice because these premises are violated under high-velocity impact. The method must therefore be discarded as an energy measuring system.

The only remaining alternate becomes the devising of a system for measuring the rupture energy directly. This would obviously be a preferred method, if a satisfactory technique could be developed since it is completely divorced from the physical characteristics of the energy input. A conclusion to this effect was reached relatively early in the course of this investigation, and a major part of the engineering time and effort which has been expended to date has been directed toward achieving a theoretical system for this direct energy measurement. To summarize this work, Engineering Report #1, entitled "A Method for Direct Measurement of the Energy of Rupture of Impact Specimens", was issued in November.

E. THE ENERGY MEASURING SYSTEM

The following comments are supplementary to the discussion of the basic theory outlined in Engineering Report #1. The present purpose is to explain in more detail the characteristics of the data signals representing "force" and "distance"; and to indicate how they are electronically related and combined into a recorded indication of "Energy of Rupture".

The output of the interferometer is a series of pulse signals whose total number may lie between 10^5 and 10^7. These signals are generated each time the striker element carrying the moving mirror of the optical system rotates through the light beam of the interferometer. Thus, these signals are repeated for each revolution of the rotating disc. The total number of pulses is constant, but the time required to generate them will vary inversely with the rotor speed. The range of this time interval is approximately

127 to 3750 microseconds, corresponding to 500 fps and 17 fps peripheral speed respectively.

For a constant rotative speed, the time duration of each individual pulse will be constant. During deceleration, the sucessive duration of each individual pulse will increase. Theoretically these pulse characteristics are a measure not only of the magnitude of the velocity, but of its varying nature as well. This is a factor of considerable importance in the final determination of rupture energy; but the pulse data as generated is not usable for this purpose without further modification. An electronic circuit is employed for converting the individual pulses of varying-time duration to pulses of constant-time duration. The frequency and total number of pulses remains unchanged, however. This is accomplished by a "flip-flop" circuit such as is used in digital computers.

The total number of pulses generated corresponds to a definite distance (or arc of travel) of the striker-mirror. This distance exceeds the distance traveled by the striker during the rupture of the test specimen. Therefore, the signal generated by the striker (force dynamometer) has a total duration corresponding to but a small fraction of the total number of pulses generated. Since the number of pulses are a function of the distance traveled by the striker-mirror, and since a force signal is being generated by the striker dynamometer only while it is in contact with the test specimen, the combined signals are proportional to energy, since E = force x distance. The characteristics of these signals, however, are varying with respect to time. Hence, an electronic circuit is required to relate "force" to "distance" in such a manner that the definite integral of one with respect to the other can be obtained.

This function is performed by a "gate circuit" in which the distance measuring pulses act as a valve to permit the force signals to flow into the energy-recording meter (ballistic galvanometer) for constant time intervals corresponding to each individual pulse. Varying quantities of electricity, proportional to the magnitude of the force signal, flow into the ballistic galvanometer for these succeeding time intervals. The cumulative charge stored in the galvanometer is thus proportional to the integrated force-distance measurements and the galvanometer can be calibrated to read directly in terms of ft-lbs.

The several functions described above are schematically illustrated in Figures #2 and # 3 . A block diagram of the complete Data System is shown in Figure # 4.

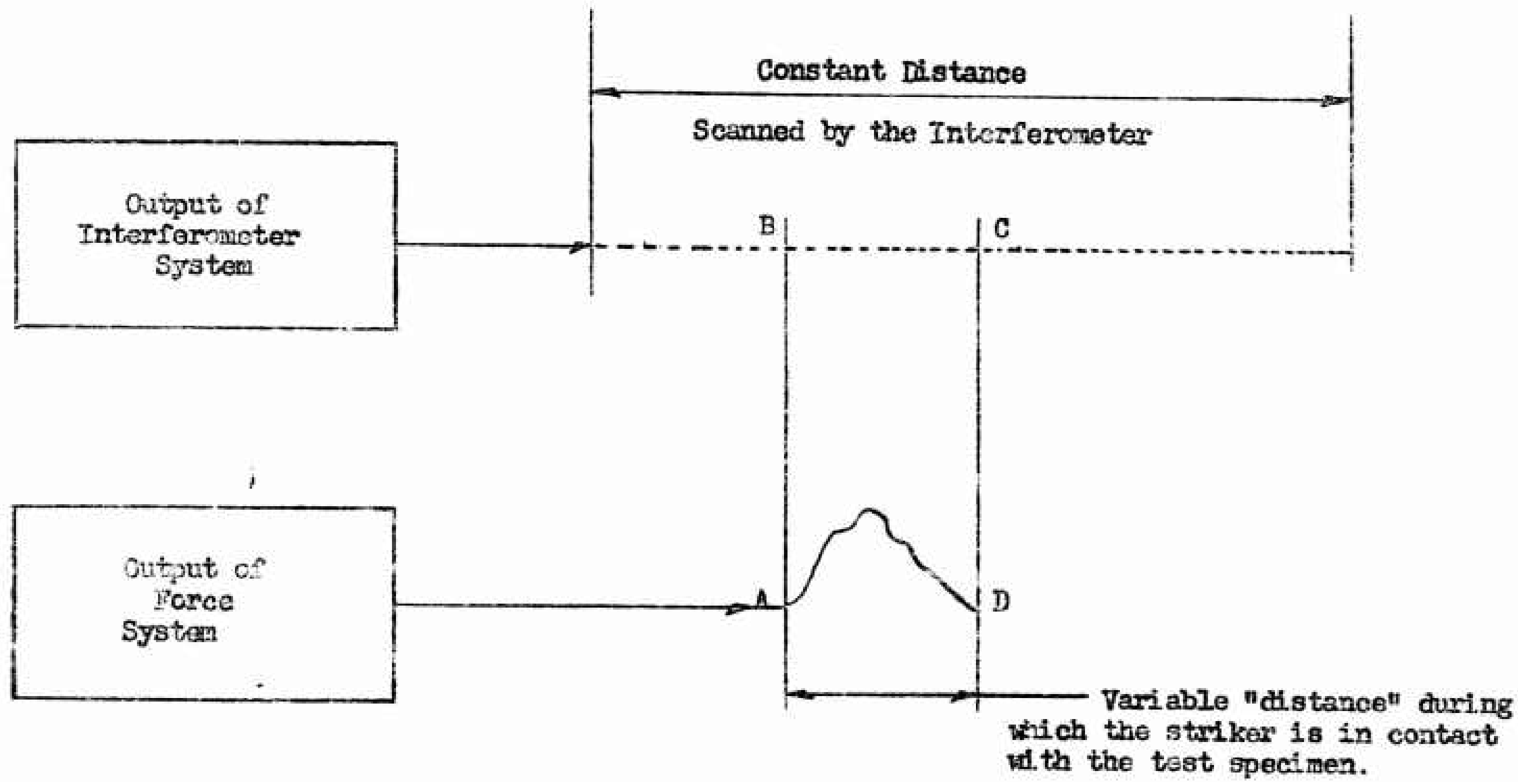
F. AUXILIARY DATA ON SPECIMEN BEHAVIOR

In the Foreword to this report, brief mention was made of impact characteristics which may have a bearing on the dynamic behavior of the test specimens. The purpose of the following paragraphs is to discuss these theoretical considerations more in detail as they relate to the proposed energy measuring system.

If we can presume a satisfactory reduction to practice of this system for measuring the energy of rupture, the primary objective will have been attained. Thereby, some justifiable reliance can be placed upon the resulting relations of rupture energies to striking velocities. It seems reasonable to expect that the plotted results of these relationships may create

Figure 2

CORRELATION OF SIGNAL DATA



The signal data bounded by the "time area" A-B-C-D is converted into Energy of Rupture by appropriate electronic networks and recording apparatus.

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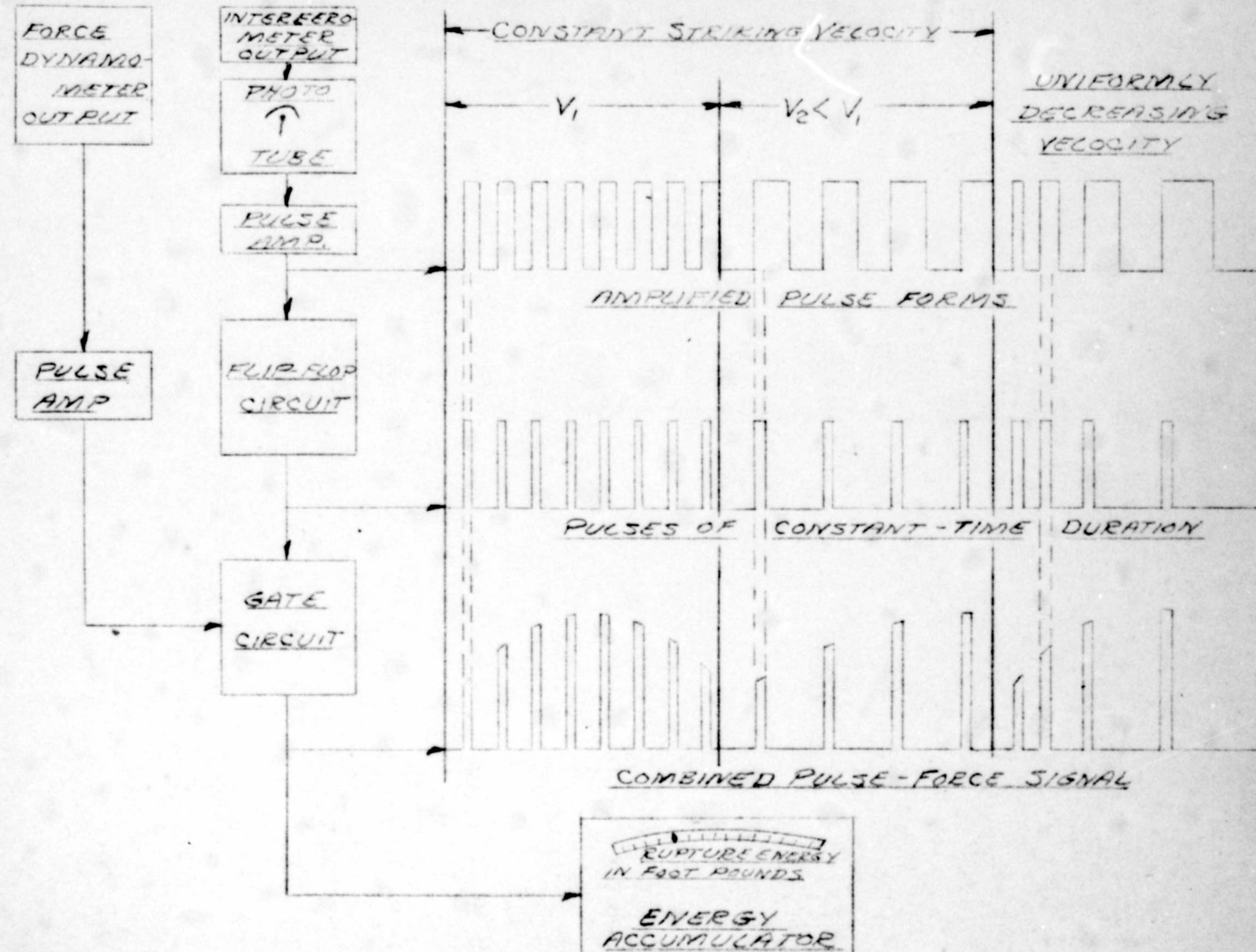
RPP 1-5-52

FIGURE 3

PULSE FORMS FOR CONSTANT TIME INTERVALS



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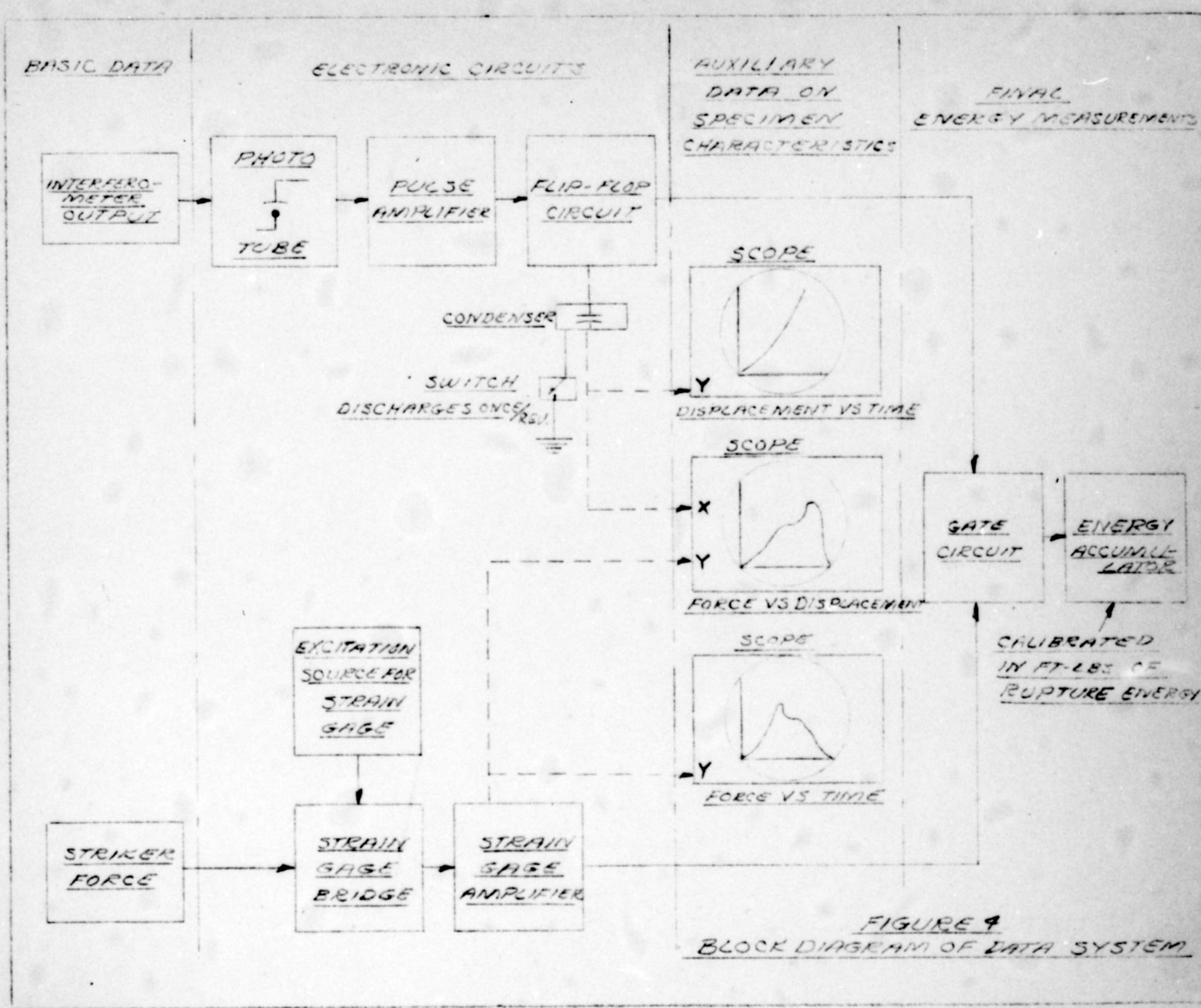

FIGURE 4
BLOCK DIAGRAM OF DATA SYSTEM

a problem of interpretation if variations in trends are observed corresponding either to the "Mann effect" or to some other major deviation. Some definite knowledge of the behavior of the specimen and/or of the rupturing force as functions of time during the "rupture cycle" may provide valuable interpretative data.

Due to the type of the measuring signals generated and to the nature of their associated electronic networks, it becomes possible to obtain and record time-varying data which may be amenable to analysis and which may yield dynamic information of considerable importance. These data might be used to delineate the following characteristics:

1. The changing nature and magnitude of the striking force.
2. The varying amounts of the energy absorbed by the test specimen as a function of the specimen displacement.
3. The nature and magnitude of the deceleration of the striking member during the rupture cycle.

The belief is currently held that the test specimen is subjected to but a single impact by the striker. This may not necessarily be true. Under certain striking velocities, multiple impacts of varying magnitudes may occur and their frequency as well as their relative magnitudes may vary not only with the striking velocity but also with the physical and metallurgical characteristics of the test specimens. It is possible that this situation occurs with the presently used test methods. But there is no means currently in use for observing and recording this condition, if it does exist. For the proposed energy measuring system, the output from the force dynamometer can be separately fed to a cathode-ray oscillograph which will record, as Force vs. Time, the magnitudes and durations of impact contacts with the specimen during rupture. Having a graphical delineation of these conditions, together with the record of the displacement of the striking force, the varying amounts of energy absorbed by the specimen can be obtained. This may supply significant information to account for specimen behavior and may help to interpret any variations in the trend of the plotted total rupture energy.

Possibly of contributary significance may be the deceleration of the striker during the rupture cycle, especially at low velocities. An oscillographic record of the interferometer data, as Displacement vs. Time, may yield data of value. By combining on the X and Y axes of a cathode-ray oscilloscope, the simultaneous data from both the force dynamometer and the interferometer, a graphical record can be obtained of Force vs. Displacement. These several data sources are indicated on the block diagram previously mentioned (Figure #4).

G. CONCLUSIONS

The results of this investigation can be briefly summarised as follows:

1. A theoretical system has been devised for high velocity impact testing, consisting of a rotative means for supplying the required energy and velocity to the striker, a movable support for the test specimen, and a means for the direct measurement of rupture energy
2. The successful integration of these several elements into a full-scale working model should yield test apparatus capable of meeting the specified requirements of both a high striking velocity and a relatively high precision

of energy measurement.

3. The feasibility of achieving this objective rests primarily upon the soundness of the theoretical means proposed for measuring the rupture energy.

4. Existing principles of physics, optics and electronics are utilized in this energy measuring system to provide sensing elements capable of producing instantaneous values of force and distance with a high degree of precision.

5. An extensive program of research and development will be required to perfect the elements of the over-all system and to integrate them into a full-scale working model.

6. A program to accomplish this objective is considered feasible and potentially capable of a satisfactory solution.

H. RECOMMENDATIONS FOR A PLAN OF PROCEDURE

It is undoubtedly recognized that a successful accomplishment of the required objective involves applied research of a high order, demanding the combined efforts of mathematicians, physicists, engineers and electronic technicians. Considerable study has been given to the nature of the problems which are involved and to methods of attack upon them. Parallel investigations of some elements are possible; but in many instances, the direction of the research will be dictated by a sequential solving of interim problems. The general nature of these investigations can be bracketed into the following elements:-

1. Design and manufacture of bench layouts and breadboard models, of interim mechanical and electronic elements. Tests and evaluation of performance for static and dynamic behavior under various exciting influences.
2. Theoretical analyses where required for the prediction and interpretation of physical and electronic responses to known input characteristics.
3. Analysis and synthises of networks to compensate for non-linearities of response.
4. Sub-contracting of special equipment and apparatus such as the optical system of the interferometer, mechanical and electronic components of the final apparatus.
5. Assembly of the complete apparatus, calibration, proof-tests.

The conduct of these various types of investigations needs to be correlated with an over-all Plan of Procedure having specific interim objectives. The first of these objectives would be the development of the striker (force dynamometer), since this is the single, most important element in the entire system. This objective will be attained if bench model setups prove the striker capable of accurately reproducing known inputs under a wide range of frequencies.

The second objective would then be the testing and evaluation of the striker under standard test conditions. This would necessitate the application of striker to a Charpy Machine and the measurement of the striker response against calibrated test specimens. The rupture energies would be obtained from a computation of the force-time traces, and these would be compared with the indicated machine results. If a satisfactory agreement of energy values can be obtained, one of the major development tasks of this program will have been accomplished.

Simultaneously with the above work, design studies of a number of mechanical and electronic details can be carried on, together with a paper study of the interferometer system. However, only a nominal amount of expermintal testing of the other elements of the system would be undertaken until a satisfactory performance of the striker is attained.

The next succeeding steps would be concerned with development of the interferometer system. First, as a bench model to study the optical and electronic performance under various control conditions. Then a study of operating characteristics when applied to a rotating disc. The development of the machine elements, power-drive, specimen-holding fixtures, interlocks and controls could be carried on simultaneously with the interferometer development.

The final stage of the program would be the testing, calibration and evaluation of the completely integrated assembly. An extensive series of tests is contemplated for this final stage, using the auxiliary data circuits for an evaluation of specimen behavior against theoretical analyses. Initial test would require considerable quantities of duplicate specimens for low-velocity testing in comparison with standard Charpy Machine tests of similar specimens. A series of tests would be performed at increasing velocities to determine the constancy of the machine characteristics as well as to provide data for theoretical analyses of energy-velocity characteristics.

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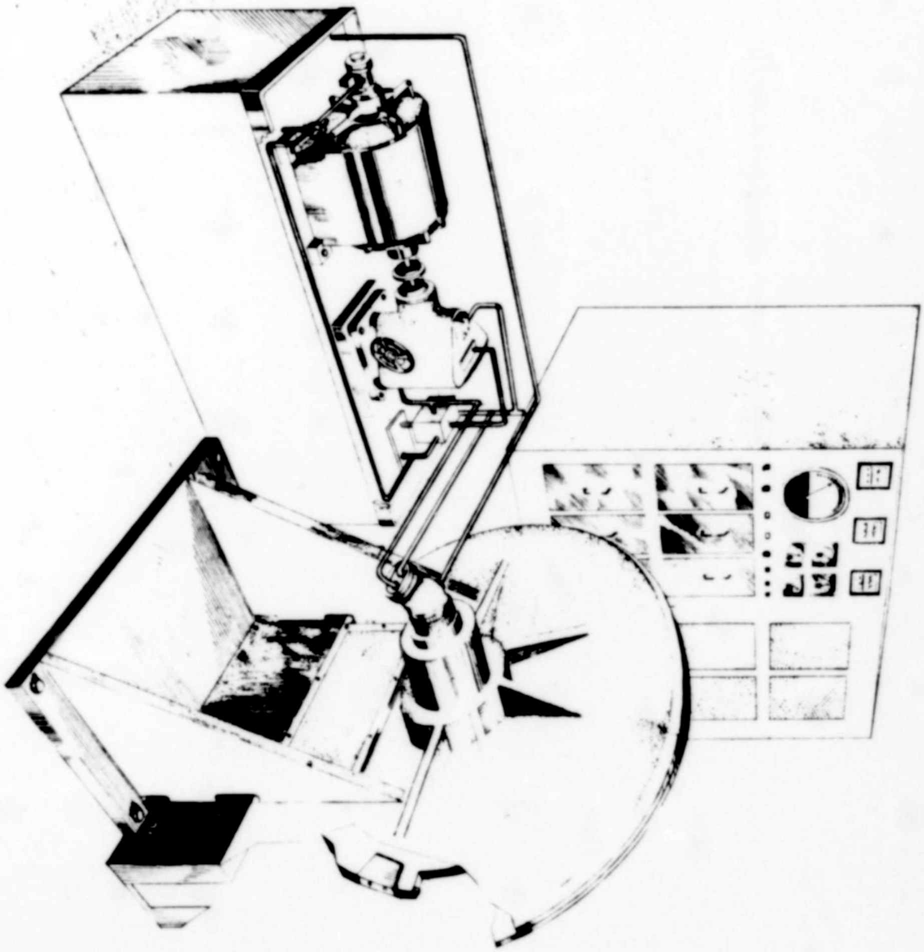
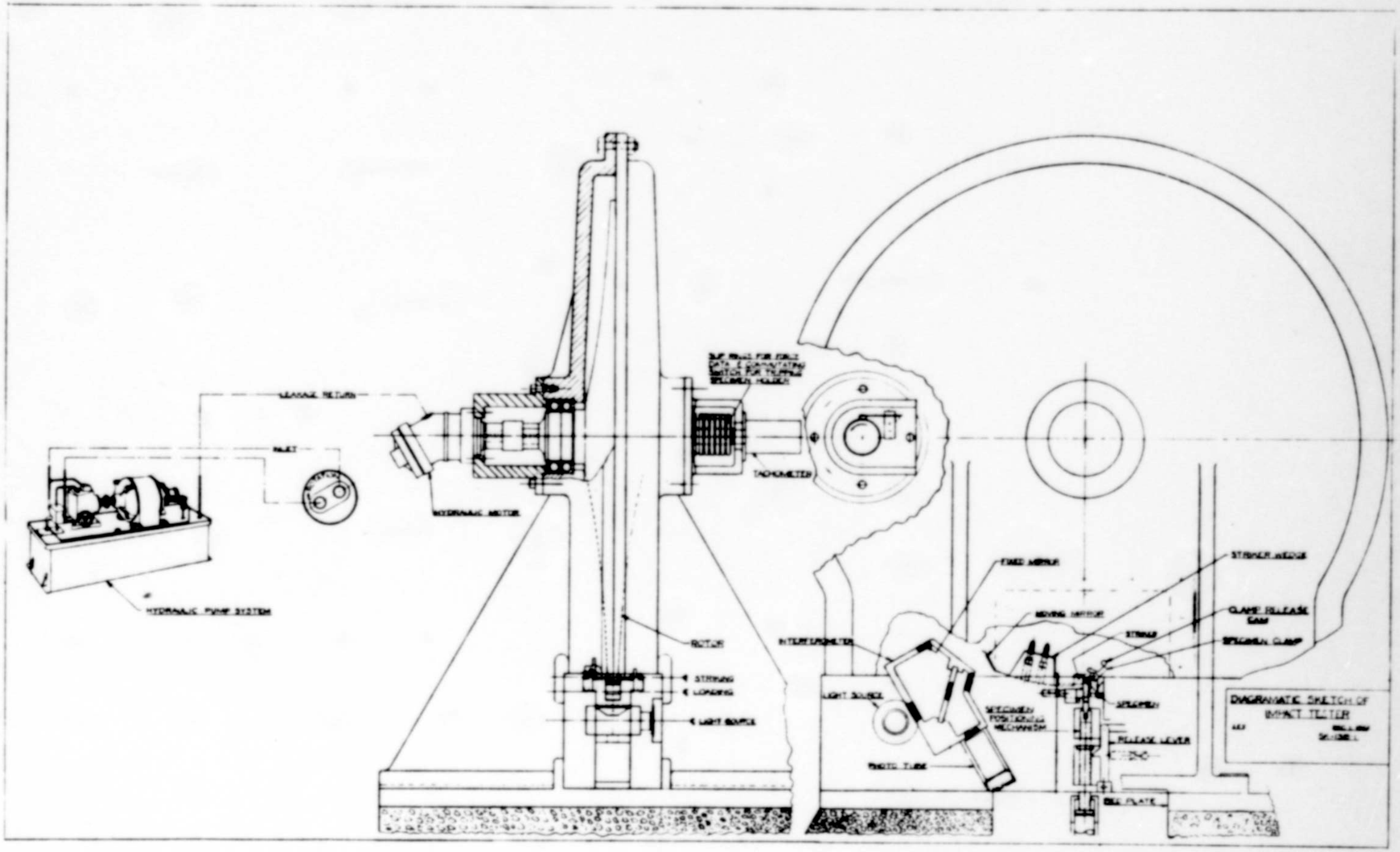
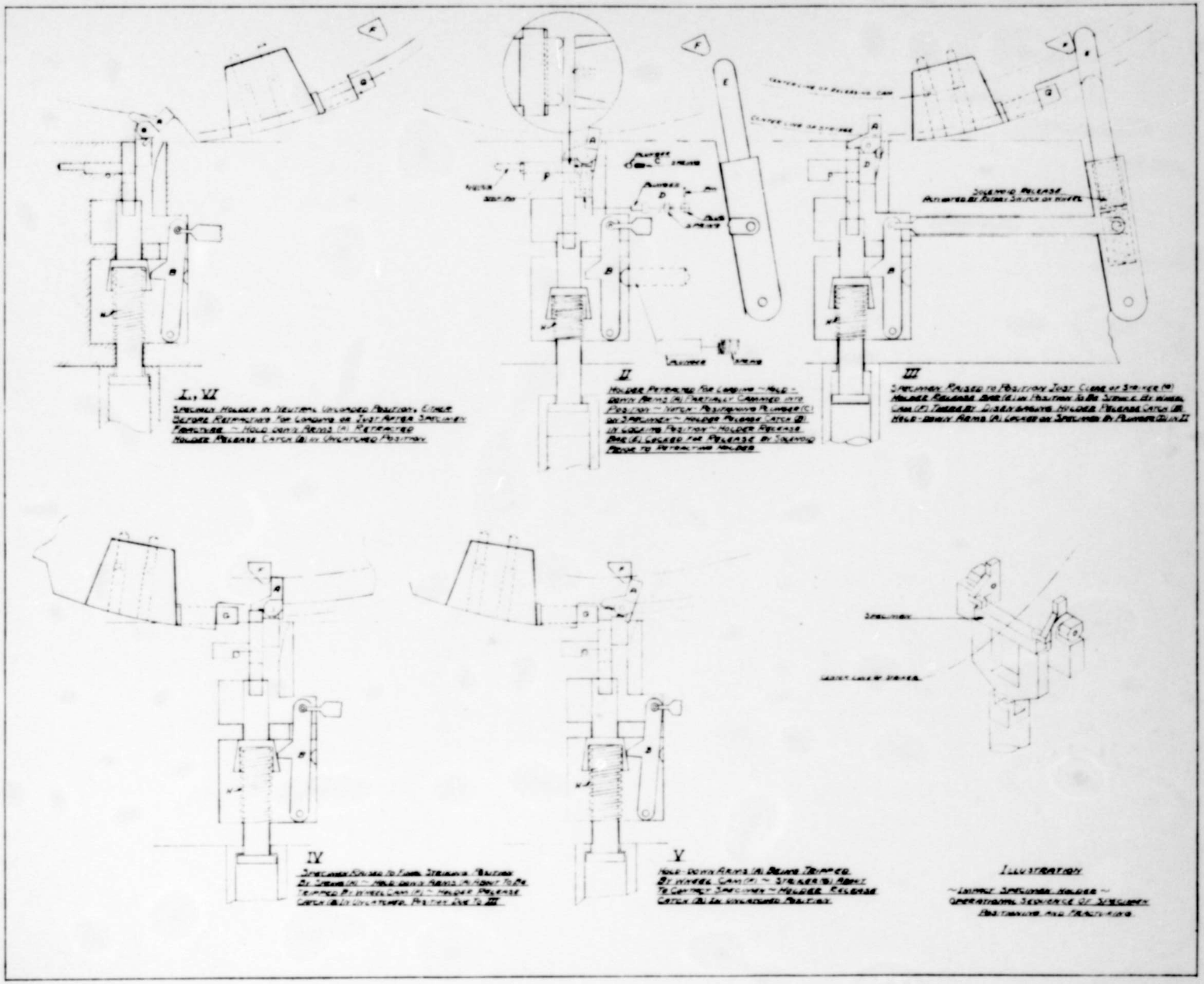



LEAKAGE RETURN
INLET
HYDRAULIC PUMP SYSTEM
HYDRAULIC MOTOR
SLIP RINGS FOR FORCE DATA & COMMUTATING SWITCH FOR TRIGGERING SPECIMEN HOLDER
TACHOMETER
ROTOR
℄ STRIKING
℄ LOADING
℄ LIGHT SOURCE
FIXED MIRROR
MOVING MIRROR
INTERFEROMETER
LIGHT SOURCE
SPECIMEN POSITIONING MECHANISM
PHOTO TUBE
STRIKER WEDGE
CLAMP RELEASE CAM
STRIKER
SPECIMEN CLAMP
SPECIMEN
RELEASE LEVER
BED PLATE
DIAGRAMATIC SKETCH OF IMPACT TESTER



I, VI
Specimen Holder in Neutral Unloaded Position, Either Before Retraction for Loading or Just After Specimen Fracture ~ Hold-Down Arms (A) Retracted
Holder Release Catch (B) in Uncatched Position
II
Holder Retracted for Loading ~ Hold-Down Arms (A) Partially Cammed into Position ~ Notch-Positioning Plunger (C) on Specimen ~ Holder Release Catch (B) in Locking Position ~ Holder Release Bar (E) Cocked for Release by Solenoid Prior to Retracting Holder
III
Specimen Raised to Position Just Clear of Striker (G)
Holder Release Bar (E) in Position to Be Struck by Wheel Cam (F) Thereby Disengaging Holder Release Catch (B)
Hold-Down Arms (A) Locked on Specimen by Plunger (D) in II
Solenoid Release
Actuated by Relay Switch on Wheel
Center Line of Release Cam
Center Line of Striker
IV
Specimen Raised to Final Striking Position by Spring (H) ~ Hold-Down Arms (A) About to Be Tripped by Wheel Cam (F) ~ Holder Release Catch (B) in Uncatched Position Due to III
V
Hold-Down Arms (A) Being Tripped by Wheel Cam (F) ~ Striker (G) About to Contact Specimen ~ Holder Release Catch (B) in Uncatched Position
Specimen
Illustration
~ Impact Specimen Holder ~
Operational Sequence of Specimen Positioning and Fracturing

APPENDIX A

COST-PLUS-FIXED-FEE CONTRACT FOR RESEARCH AND DEVELOPMENT

Contract No. DA-19-020-ORD-1792

Department of the Army - Ordnance Corps

Contract for: "Research on Impact Testing"

Amount: $12,575.00

Date of contract: 26 May 1952

ARTICLE I - Scope of Work

a. The objective of this theoretical study is to determine the feasibility of developing, designing, and constructing apparatus for the impact testing of ferrous and non-ferrous specimens and materials under various conditions of striking velocity, including high-velocity, at room temperature and at low temperature. This study will include, but not necessarily be limited to, analysis and design considerations of the following items:

(1) Theoretical aspects of the design parameters pertinent to the system as a whole, such as

(a) Striking velocities

(b) Energy in-puts

(c) Rates of specimen loading

(d) Geometry of the striking surface

(e) Geometry of the specimens under test

(f) Inherent system errors

(g) Space limitations

(2) Linear versus rotative systems for loading the specimens being tested.

(3) Systems of instrumentation for measuring data essential to an evaluation of the specimen performance.

(4) Schematic design studies of one or more complete systems of test apparatus, engineering layouts, circuit diagrams, and sub-assembly details, where needed to delineate the functioning of the various elements of the equipment.

(5) Summary report of findings and supporting data for recommendations and conclusions.

A P P E N D I X B

SUMMARY OF STAFF PERSONNEL

Classification and Distribution of Total Hours

Classification	Total Hours	%
1. Engineering	1955	83
2. Designing & Drafting	229	10
3. Reporting & Clerical	168	7
TOTAL	2352	

1. Engineering Staff:-

Frank C. Hutchison - Technical Director
Edward S. Prohaska - Project Engineer
John B. Zornig - Engineer
Andreas M. Koehler - Jr. Engineer
Nathan M. Fales - Jr. Engineer
Henry F. Timmons - Jr. Engineer
Paul V. Choate - Jr. Engineer
Richard W. Stripp - Jr. Engineer
Irving Frank - Jr. Engineer

2. Designing & Drafting Staff:-

John F. Young - Design Engineer
Morton J. Thorburn - Technical Illustrator
Henry A. Horton - Technical Illustrator
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APPENDIX C

ENGINEERING PLAN OF PROCEDURE FOR THE DEVELOPMENT OF A PROTOTYPE HIGH-VELOCITY IMPACT TESTING MACHINE

The following outline is a tentative plan of attack for accomplishing the above objective. The research and development phases would, in general, follow sequentially as outlined.

I. DEVELOPMENT OF STRIKER DYNAMOMETER

A. - Paper Design of Striker with Strain Gage.

1. Modification of design to permit determination of frequency response.
2. Paper design of required electronics (power supplies, excitation sources, amplifiers, etc.).
3. Design of test equipment (Sine generator, measuring apparatus, etc.).

B. - Manufacture and Development of A (1 to 3).

1. Experimental determination of response.
2. Analysis and synthesis of networks to compensate for non-linearities in response.
3. Experimental check of compensated response.

C. - Application of Striker to Standard Charpy Machine.

1. Modification of standard machine for striker.
2. Bread-board setup to measure striker response against standard specimens computing energy from force-time traces and comparing with standard machine results.
3. Analysis of data.
4. Striker modification.

D. - Design and manufacturing of pulse generator to simulate phototube output.

E. - Design and construction of pulse amplifier, flip-flop, gate, and ballistic galvanometer.

F. - Recheck of dynamometer output on standard specimens when connected into interferometer circuit with pulse generator interrupting circuit.

1. Test.

2. Modification of compensating network, if necessary, due to interaction.

G. Final check of force dynamometer at 17 fps on Charpy machine.

II. DEVELOPMENT OF INTERFEROMETER
(Coincidentally with Wheel)

A. - Paper Design of System (To be done in conjunction with wheel).

1. Moving mirror design.
2. Fixed mirror system.
3. Light source and mounting.
4. Phototube mounting and electric cabling.
5. Housing for 1 to 3.

B. - Electronics and Amplifiers, etc. Design (Refer to I-E).

1. Pulse amplifier.
2. Flip-flop circuit.
3. Gate circuit.
4. Energy accumulator.

C. - Subcontract.

1. Design of moving mirror.
2. Design of mirror (fixed) system, light source and phototube assembly.

3. Manufacture and test.

D. - Bench Test of Interferometer System.

1. Static light flashes to check electronics.

2. Sinusoidal oscillation of moving mirror.

3. Rotation of moving mirror against micrometer screw.

E. - Assembly to Wheel.

1. Assembly and adjustment.

2. Test

III. DEVELOPMENT OF MACHINE ELEMENTS

A. - Mechanical Design.

1. Wheel and mounting.

2. Drive system

a. Variable speed drive system

b. Speed control

3. Speed measuring system.

4. Adaptation of striker to wheel

a. Charpy test

b. Izod test

c. Tension test

5. Adaptation of interferometer system to machine.

6. Design of specimen holding fixture.

a. Charpy (attention to keeping notch cold on low-temperature specimens)

b. Izod (")

c. Tension

B. - Experimental Development

1. Holding fixtures.

2. Mirror (moving) and striker adaptation.

3. Transmission of force data to electronics (cabling and slip rings; preamplifier on wheel)

C. - Manufacturing and Procurement of items under (A).

IV. ELECTRICAL WIRING AND ELECTRONICS

A. - Wiring layout.

1. Motor

2. Tachometer

3. Data system

4. Electronic chasses and racks

B. - Manufacturing

C. - Assembly, cabling and test

V. ASSEMBLY AND TEST OF COMPLETE MACHINE

A. - Assembly.

B. - Routine checks and speed tests; checks of interferometer output.

C. - Specimen Testing.

1. Comparison with Charpy.

2. Comparison of energy recorder with planimetered force-distance curves.

3. Check on substitution of force-time data at higher speeds.

D. - Machine acceptance.

APPENDIX D

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